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**Date(s) and time(s) experiment was performed\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**ECE 3155**

**Experiment V**

**OTHER OP AMP CIRCUITS**

Revised dps August 2025

**Introduction**

There are a variety of op amp circuits that perform functions that we have discussed in previous courses. Among these functions are negative resistance and current sources. The purpose of this experiment is to allow you to see that these functions exist as op amp circuits in actual circuits.

***Input and Output Resistances***

Remember the definitions for input and output resistances. The **Input Resistance** is defined as the Thevenin equivalent resistance as seen by the source attached to an amplifier, with the load in place. Sometimes the load affects the input resistance in a significant way, and sometimes it does not. That depends on the particular amplifier circuit being considered. Note that reference to amplifiers should make it clear that **Input Resistance** is inherently a signal quantity. In a similar way, the **Output Resistance** is defined as the Thevenin equivalent resistance as seen by the load attached to an amplifier, with the source in place. Again, the source sometimes affects the output resistance in a significant way, and sometimes it does not. The **Output Resistance** is also an inherently signal quantity. We are going to look at the **Input Resistance** of a particular circuit to see how it behaves.

 It is not uncommon to hear students claim that there is no such thing as a **current source**. One of the goals of this experiment is for students to refute this claim by making measurements on a circuit that behaves as a **current source**. For practical purposes, a circuit or device that behaves as a **current source** is actually a **current source**. Stated in other terms, if the device delivers the same current to a wide variety of resistance values, then for those resistance values that device is a **current source**. We will build a device that behaves as a **current source**, where the value of the **current source** is given by a voltage source value, divided by a resistance value. For this experiment, the resistance that is connected to the **current source** cannot be grounded, so we will measure its voltage with the multimeter, and not the oscilloscope. It is possible to build a **current source** that allows the resistance to be grounded, but it is more complicated, and we will leave that example for another time.

**Components Required**

Assorted resistors and capacitors from the lab kit

Resistance Substitution Box (labeled Power Resistor Decade Box or Decade Resistor in the laboratory)

3 different 741 op amps

**Procedure**

***An Op Amp Amplifier with Positive Feedback***

1. On your breadboard, build the circuit shown in Figure 1, using a 741 op amp from your lab kit. Remember to connect dc power supplies to pins 7 (+15[V]) and 4 (-15[V]). For the switch, you do not need a formal switch. You may simply have a wire that can be inserted and removed as needed to include the 270[kW] resistor and take it out of the circuit. If you have access to a switch, you may include it, but there is not a switch included in your lab kit.

The voltage source *vs* in this diagram will be the signal generator (Arbitrary Waveform Generator) available to you in the laboratory. Set this generator to produce a sine wave with an amplitude around 2[Vpp], no dc component, and a frequency of 600[Hz]. The signal generator has an internal resistance equal to 50[W], so the 22[kW] resistor here will be a separate resistor that you will add to the circuit. Using our engineering approximations we should see that the equivalent series resistance is effectively 22[kW].

Set the switch to be open, or take the wire out, so that the 270[kW] resistor is not connected. Measure the peak-to-peak voltage at point C with respect to ground using the oscilloscope. You can make this measurement with the voltmeter, but if you do, you will not be able to detect the phase relationships, which will be important later. Calculate what you are expecting to measure at this point, from an analysis of the op amp circuit, again with the switch open. These two values should be pretty close. If they are not, debug your circuit until the measurement and calculated value are close in value.



**Figure 1.** The First Op Amp Circuit. This circuit has positive feedback when the switch is closed.

Table 1 – Measured and Calculated Values for the Voltage at Terminal C.

|  |  |
| --- | --- |
| Measured *vc,pp* |  |
| Calculated *vc,pp* |  |

1. Now close the switch or insert the wire so that the 270[kW] resistor is in the circuit. At this point the resistor is providing positive feedback, as it connects the output signal to the noninverting input of the op amp. Again, measure the peak-to-peak value of the voltage at terminal C with respect to ground. Also measure the peak-to-peak value of the voltages at terminal A, and at terminal B. Measure the voltage source as well. From your measured values, you should be able to calculate the current *is* by using Ohm’s Law for the 22[kW] resistor. Record your values in Table 2.

Table 2 – Measured Values of Voltages and Calculated Current

|  |  |
| --- | --- |
| Measured *vc,pp* |  |
| Measured *va,pp* |  |
| Measured *vb,pp* |  |
| Measured *vs,pp* |  |
| Measured *va* at the time of the peak value |  |
| Measured *vs* at the time of the peak value |  |
| Calculated *is* at the time of the peak value |  |

1. Note that the sign of the current *is* is important here. Look at the peak value of *vs* and *va* on your oscilloscope at the same time. Do both peaks occur at the same time? If they do, then you can use those values to calculate the sign of *is*. Enter the peak values you measure for these two voltages in Table 2. Make sure that you understand the sign that you obtain from the Ohm’s Law equation for *is*. Although it gives away the answer, we will note here that you should find that the calculated value of *is* is negative.
2. Use the values you have for *vs* and *is* to calculate the input resistance seen by the signal source *vs*.
3. Use the values you have for *va* and *is* to calculate the input resistance seen by the Effective Source as defined in Figure 1. Note that this Effective Source is made up of the combination of the signal generator and the 22[kW] resistor. What is the sign of this resistance?

***Two Op Amps Connected to a Load, RX***

1. For the next circuit, we will need two op amps. See the circuit in Figure 2. We will be using several different resistor values for the resistor *RX*, so you may wish to use one of the resistance substitution boxes in the laboratory for *RX*. You will use the A Supply and the B Supply from your DC Power Supply to provide +15[V] and -15[V] for your op amps. Use the third dc voltage source, labeled 2-6.5[V], as your input voltage *vS*. The input will be a dc quantity, and the output will also be a dc quantity. Thus, you can make measurements of *vX* with your dc voltmeter for this portion of the experiment. Build the circuit, and attach the usual DC power supplies to the op amps, at pins 4 and 7.



**Figure 2.** TheSecond Op Amp Circuit. Be sure to connect the dc power supplies to the two op amps, as before. The voltage source *vS* will be the 2-6.5[V] dc source in your DC power supply.

1. Start with a value of *vS* of 2.5[V], and an *RX* value of 1[kW]. Make sure that your op amps are working properly. For this situation, both op amps should have negative feedback, and thus the voltage at the inverting and noninverting inputs should be equal. Make sure that they are indeed equal before moving forward. Note that we have not shown ground anywhere in this circuit. The power supplies for the op amps are grounded, and *vS* can be grounded, but does not need to be grounded. Do not connect either end of either resistor to ground.
2. Measure the value of *vX* across *RX* with your voltmeter. Do not make this measurement with your oscilloscope, since one end of your oscilloscope probe is grounded. From this measured value and *RX*, solve for *iX* flowing through *RX*. Then, increase the value of *RX*, and repeat your measurements and calculations. Choose at least ten values of *RX* between 1[KW] and 40[kW]. Plot *iX* as a function of *RX* using your measurements.
3. Using a particular value of *RX* such as 10[kW], vary the source *vS* over a range from 2[V] to 6[V]. Again, choose about ten values of *vS*. For each value of *vS*, measure *vX* and calculate the value of *iX* that results. Plot *vS* as a function of *iX*. What is the slope of your plot?
4. Look at the results in your plots. Consider that you are viewing *RX* as the output (the Load) and the rest of the circuit as a Thevenin or Norton equivalent. How would you model the rest of the circuit, as seen by the Load, based on your results?

**Questions**

1. What does it mean to have a negative resistance? Is it true that negative resistances always deliver positive power? Is it possible for a resistance to deliver positive power?

2. Is it possible to have a voltage source? Is it possible to have a current source? Remember when you answer these questions that you should answer in terms of the viewpoint of an engineer, who will approximate to get a good enough answer for the problem situation.

3. Did any of the op amps you used in this experiment go into saturation? If the op amps had saturated in either of these two circuits, would the behavior of the circuits have changed?